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## Appendix 1

Olsson and Bolin (2014) showed that for a fitness maximizing central place forager, the maximum travel distance of individual  $m$  of species  $s$ , should be

$$\tau_{m,s}^* = \frac{E_m - L_s}{E'_s} - \frac{xp_m W_1}{p'_s} \quad (1)$$

and the constant describing the tradeoff between travel distance and patch quality

$$\omega_{m,s} = \left( \frac{xp_m}{p'_s} (W_1 - W_2) - \frac{E_s}{E'_s} \right) L_s \quad (2)$$

where  $E_m$  is the energy harvested by the individual,  $L_s$  is the loading capacity of the species,  $p_m$  is the individual's long-term survival rate,  $x$  is a positive constant  $<1$  that describes the diminishing returns of fitness with energy intake, and  $E'_s$  and  $p'_s$  are negative constants defining the changes with travel time in energy reserves and survival rate, respectively, and  $E_s$  is the change in energetic state with foraging time.  $W_1$  and  $W_2$  are Lambert-W functions that themselves depend on the other terms in the expressions (see Olsson and Bolin 2014 for full details). An individual in a rich environment will have high  $E_m$  and  $p_m$ , and will therefore not travel as far as an individual in a poor environment, but species with low travel costs will be able to go further than those with high travel costs.  $\omega_{m,s}$  summarizes the trade-off between energy gains and travel costs; species with low travel costs will have a steeper tradeoff (Fig. 1 in the main paper). The numerical values for all parameters used in the in simulations in the paper are presented in Table 1.

Selecting the optimal set of patches to include in the habitat, which maximizes fitness in an explicit landscape, involves sequentially including the patches with the highest marginal fitness benefit,  $\Delta_{i,m}$  (Eq. 1 in the main paper) until all patches below the curve, given by  $\tau_{i,m} = \tau_{m,s}^* - \omega_s / A_i$  in Fig. 1, have been used (Olsson and Bolin 2014). The reason it has to be done sequentially is that, as mentioned above,  $\tau_{m,s}^*$  itself is dynamic with respect to the patches chosen (Olsson et al. 2015) as it depends on  $E_m$  and  $p_m$ . To calculate fitness and the optimal solution we need:

$$E_m = N_m L_s + E_s \sum_{i=1}^{N_m} t_{i,m} + E'_s \sum_{i=1}^{N_m} \tau_{i,m} - (E_s + c_s) T_s \quad (3)$$

and

$$p_m = e^{p_s \sum_{i=1}^{N_m} t_i + p'_s \sum_{i=1}^{N_m} \tau_i - (p_s + \mu_s) T_s} \quad (4)$$

as  $G_m = p_m F_m$ , where  $F_m = E_m^x$ . In Eq. 3 and 4  $N_m$  is the total number of patch visits made by individual  $m$ ,  $c_s$  is the metabolic and  $\mu_s$  the mortality rate while foraging,  $p_s$  is the change in survival rate with foraging time, and  $T_s$  is total time interval until reproduction. It can also be shown (Olsson and Bolin 2014) that  $E_s = c_s (\alpha_s - 1)$ ,  $E'_s = c_s (\alpha_s - \beta_s)$ ,  $p_s = \mu_s (\delta_s - 1)$ , and  $p'_s = \mu_s (\delta_s - \varepsilon_s)$  where  $c_s \alpha_s$  is the metabolic rate in the nest, and  $c_s \beta_s$  is the metabolic rate while travelling, and correspondingly  $\mu_s \delta_s$  and  $\mu_s \varepsilon_s$  are the mortality rates while at home and travelling, respectively.

Each individual's strategy is flexible and dynamic in response to environmental quality, such that for each additional patch that has been included in the habitat,  $\tau^*$  will decline (Olsson and Bolin 2014). In an environment with sparse foraging resources an individual would be forced to select patches further away which will have negative effects on its fitness and the opposite would occur in an environment with abundant resources. That is, the higher the fitness prospects of an individual, the more restrictive it will be in terms of patch selection.

Since all patches that have been used have been subjected to depletion, and since an individuals' marginal energy gains are diminishing by every foraging bout, the marginal value of including another patch,  $\Delta_{i,m}$ , will decrease depending on both the landscape individual  $m$  is in and the foraging decisions made by itself and its neighbors. All individuals will continue to add patches to their habitat until they can no longer add another with  $\Delta_{i,m} > 0$ . When this condition is met, which is dependent on the aforementioned reasons and not a predefined threshold, all individuals have performed optimal patch choice in their respective environments. In this process, patch qualities and nest locations are stochastic, but patch choice by the individuals in a given circumstance is deterministic. Individuals whose patches have been depleted due to competition to a level in which fitness approaches zero will be regarded as dead. These foragers will not be able to select or deplete any patches. These deaths could occur at any iteration of the habitat selection; however, most often they occur in the beginning of the habitat selection process. If an individual dies the habitat selection starts over without that individual in the landscape. The reason for this is that an introduction of too many foragers at the start of the process could result in perverse situations where the model would predict that the whole landscape would be unsuitable for any forager since all

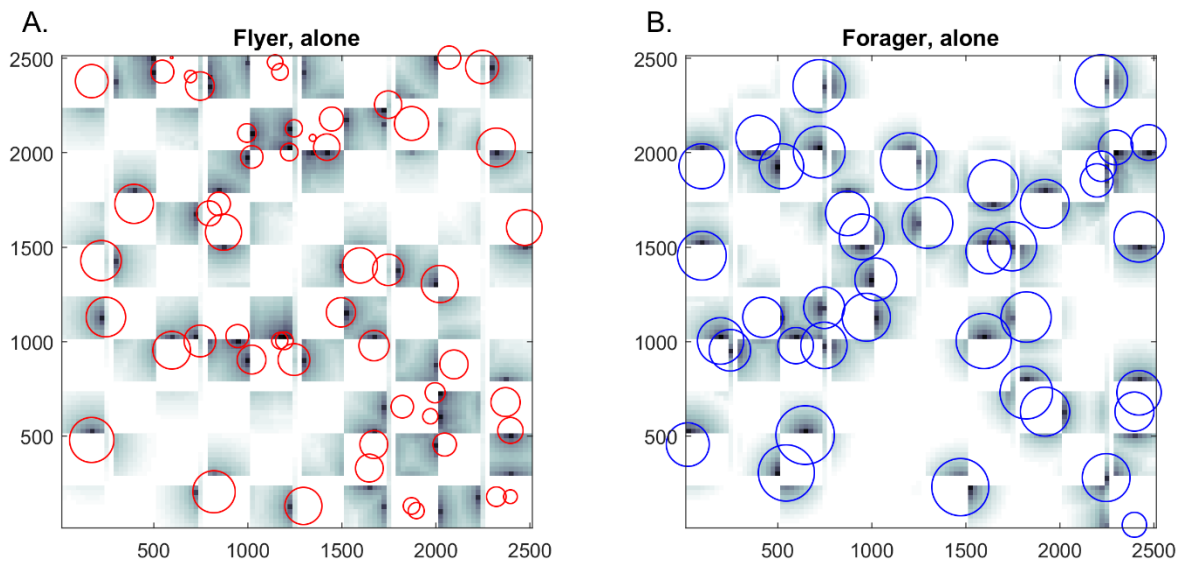
patches would be depleted to such a low state that fitness never could be greater than zero.

The life history traits that govern these tradeoffs in our model are metabolic costs and susceptibility to predation. While these tradeoffs may not always co-occur in nature they produce differences between species in the distance–quality state–space, i.e.  $\omega$  and  $\tau^*$ , which determine the foraging decisions made by individual foragers. Specifically, the species differ in the metabolic rate while foraging,  $c$ , which can be thought of as their basal metabolic rate and their metabolic rate while travelling,  $c\beta$  and the predation rate while foraging  $\mu$ , and while travelling,  $\epsilon\mu$  (Table 1). We make the argument that in order to be able to fly longer distances they must compensate this by using richer patches and will therefore have a higher basal metabolic rate (Hedenström and Ålerstam 1995, Westphal et al. 2006, Nitepold et al. 2009).

Table 1. Parameters used in the model to describe the two species' life histories. For detailed descriptions see Olsson and Bolin (2014). The units of the parameter are in the form of non-dimensional (nd), time units (tu) and energy units (eu) or distance (km). The values are conceptual but balances travel time and foraging time in a way that is appropriate.

Parameter	Value		Description	Units
	Flyer	Forager		
$\alpha$	0.1	0.1	Metabolic rate multiplier while sitting in the nest	nd
$\mu$	0.002	0.0005	Predation rate while foraging	nd/tu
$c$	4	1	Metabolic rate while foraging	eu/tu
$L$	4	4	Load size of the forager	eu
$\beta$	1.1	8	Metabolic rate multiplier while flying	nd
$\delta$	0.1	0.1	Predation rate multiplier while sitting in the nest	nd
$\epsilon$	1.1	8	Predation rate multiplier while flying	nd
$T$	250	250	Length of the season	tu
$v$	1	1	Flight speed	km/tu
$x$	0.75	0.75	Describing diminishing return	nd

## Spatial outcome in landscape E



A single simulated outcome from landscape E (refer to Fig. 2 in the main paper) is shown with *Flyers* and *Foragers* occurring alone in the landscapes, in (A) and (B) respectively. Shading indicates the visitation rate, and the circles indicate the location of the nests with the size representing fitness. The situation (A), where the flyer survives alone, is the only stable outcome, and the situation in (B) with only foragers is an unstable point.

## References

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